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NASA
FEASIBILITY STUDY
LIQUID HYDROGEN PLANT

Kennedy

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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON, D. C.

FEASIBILITY STUDY - LIQUID HYDROGEN PLANT

30 TONS PER DAY

JOHN F. KENNEDY SPACE CENTER
FLORIDA

BECHTEL ASSOCIATES PROFESSIONAL CORPORATION

MAY, 1975

NASA

FEASIBILITY STUDY - LIQUID HYDROGEN PLANT

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EXECUTIVE SUMMARY

In response to the scope outlined in Contract NASW-2809 (Code JHC-1), Bechtel submits this report on a facility to produce 30 tons per day of liquid hydrogen. The processing scheme is aimed at ultimate use of coal as the basic raw material. For back-up, and to provide assurance of a dependable and steady supply of hydrogen, a parallel and redundant facility for gasifying heavy residual oil will be installed on a priority schedule.

Both the coal and residual oil gasifiers will use the partial oxidation process. The Texaco processes are used as a basis of this estimate. The Texaco partial oxidation process for gasifying residual fuel oil is fully proven in a large number of commercial plants in many countries. The Texaco process for coal has been under active development at the pilot level for more than a year.

In support of the two gasifiers, an air separation plant will be installed to provide oxygen at 99.5 percent purity. This plant will be sized to generate sufficient oxygen for the coal based plant. This would leave excess capacity of approximately 75 tons/day of oxygen when only the oil facility is in operation. Storage is provided for this excess oxygen for use in 7-8 day shake-down runs on the coal based facility - a circumstance which may be required because of the developmental status of the coal based process.

Each gasifier will be provided with its own facilities for removal of particulates (soot and ash), and recovery of heat from the hot gas. Cooled, clean gas (still containing sulfur) is then conveyed to a single purification train which would be used with either the oil or coal based gasifier. This purification train desulfurizes the clean gas and converts it to hydrogen of 95-97 percent purity.

While the coal facility is being "shaken down," it is planned to operate the oil facility. Under these circumstances, the gas from the coal based unit will be incinerated in a thermal oxidizer while the oil unit will be providing hydrogen to the liquefier.

The final process unit is the hydrogen liquefier. This unit uses nitrogen refrigeration to provide the initial chilling of the hydrogen. Final purification of the raw hydrogen is accomplished prior to liquefaction. Ortho-para conversion is also provided within the unit.

For the purpose of preparing the capital estimate, a number of proprietary processes has been included in the process flow scheme. These are listed below.

Process	Purpose	Licensor
Partial Oxidation of Fuel Oil	Gasify Oil	Texaco Development Corp.
Partial Oxidation of Coal	Gasify Coal	Texaco Development Corp.
Rectisol	Remove Acid Gases (H_2S & CO_2) from Raw Gas	Lurgi or Lotepro Corp.
Selexol	Final CO_2 removal from Hydrogen-rich Gas	Allied Chemical Co.
Stretford	Separation of H_2S from CO_2 and conversion to Sulfur	British Gas Corp.

The cost of the hydrogen liquefier was developed on information provided by American Air Liquide.

While the above processes are considered to be representative and competitive, the final selection may differ in specific instances. Three cautionary notes are in order.

- All information in this study is preliminary in nature and may be revised on more detailed analysis. Specifically, the processes selected may be substituted by others, and therefore the results of this study are not applicable for construction purposes without further study.

- In the event the project proceeds beyond this stage, the various parties involved should be prepared to enter into secrecy agreements followed by licensing agreements as required by circumstances and licensors.

- American Air Liquide provided basic figures used by Bechtel for the development of the capital estimate of the hydrogen liquefier. They do not consider their process proprietary, but they do impose restrictions on the use of their designs for construction of plants beyond the ones for which they contract.

The capital cost of the facility is estimated to be $97 million. This estimate is based on siting the facility at the Kennedy Space Center at Cape Canaveral.

SCOPE OF PROJECT

The scope of the project is a complete, operable facility, generally as shown in Figure 3, Plot Study for Space Allocation, and as described herein.

Process Facilities

The process scheme for the Liquid Hydrogen Plant is such that residual oil and/or bituminous coal will be gasified to produce a stream of gas rich in hydrogen which is purified and then liquefied as a final product. The liquid hydrogen will be produced at a rate of 30 tons per stream day and have a purity of 99+%.

The process envisioned will consist of the following units:

Plant No.	Description
1	Air Separation
2	Partial Oxidation - Oil
2A.1	Partial Oxidation - Coal
2A.2	Coal Receipt and Preparation
3	High Temperature Shift
4	Gas Purification (Rectisol)
5	Fine Desulfurization
6	Low Temperature Shift
7	Bulk CO_2 Removal
8	Dehydration and Trace CO_2 Removal (Molecular Sieves)
9	Hydrogen Liquefaction
10	Stretford Sulfur Recovery

Offsites and General Facilities

Offsite and General Facilities contemplated for the LH_2 Plant comprise the following:

Offsites and General Facilities (Continued)

Control/Laboratory/Office Building
(Approximately 60 ft. x 80 ft. in size, single story)

Utility Building (Including small storage area)

Compressor Shelters

Coal Preparation and Storage Shed

Miscellaneous Shelters As Required

Perimeter Fencing, Roads, Walkways and Parking Area

Two Rail Spurs

Liquid Hydrogen Storage (2 - 300 ton capacity spheres)

Two Liquid Hydrogen Truck Loading Spots

In-Process Liquid Oxygen Storage (1 - 1,200 ton capacity sphere)

Residual Oil Feedstock Storage (2 - 20,000 Bbl. tanks)

Coal Storage - 1,000 tons capacity (Part of Plant 2A.1)

Fuel Oil Storage (2 - 35,000 Bbl. Tanks)

Naphtha Storage (1 - 3,000 Bbl. Tank)

Sulfur Storage - 160 tons capacity

Fire Water Storage (1 - 15,000 Bbl. Tank)

Cooling Tower Make-up Water Storage (1 - 5,000 Bbl. Tank)

Treated Water Storage (1 - 2,500 Bbl. Tank)

Offsites and General Facilities (Continued)

Process Day Tanks As Required
For Oil Feedstock
Coal Feed Slurry
Black Water Slurry
Naphtha
Miscellaneous

Water Treating Plant for BFW

Steam Generation Facilities (2 - 75,000 lb./hr. Package Boilers @ 500 PSIG, Saturated)

Induced Draft Cooling Tower (1 - 2 Cell Unit @ 10,000 GPM, 25°F Rise)

Refrigeration Plant (1 - 265 Ton Packaged Freon Unit)

API Type Oil Separator and Slops Tank (To Recover Oil Spills)

Vent Stack

Thermal Oxidizer (For Use During Start-up of Coal Partial Oxidation Unit)

Primary Power Substation and Distribution System (Approximately 35,000 KVA Capacity, Dual Source, with Automatic Throw-over Capability)

Steam Distribution and Condensate Return Systems

Systems

Potable/Sanitary Water System (City Water Quality)

Water Treating Supply/Cooling Tower Make-up System (City Water Quality)

Treated Water System (For BFW Make-up)

Boiler Feed Water System

Systems (Continued)

Cooling Water Circulation System

Fire Water System (Interconnected with KSC System)

Utility/Service Water System (Raw Water)

Instrument and Plant Air System

Fuel Oil System

Refrigeration System

Uninterruptible Power Supply
(For Electronic Instruments)

Nitrogen Purge System

Hydrogen System (For Catalyst Reduction, If Required)

Relief, Blowdown, Purge and Vent Systems

Storm Water, Process and Sanitary Sewer Systems

Plant Lighting System

Communications System

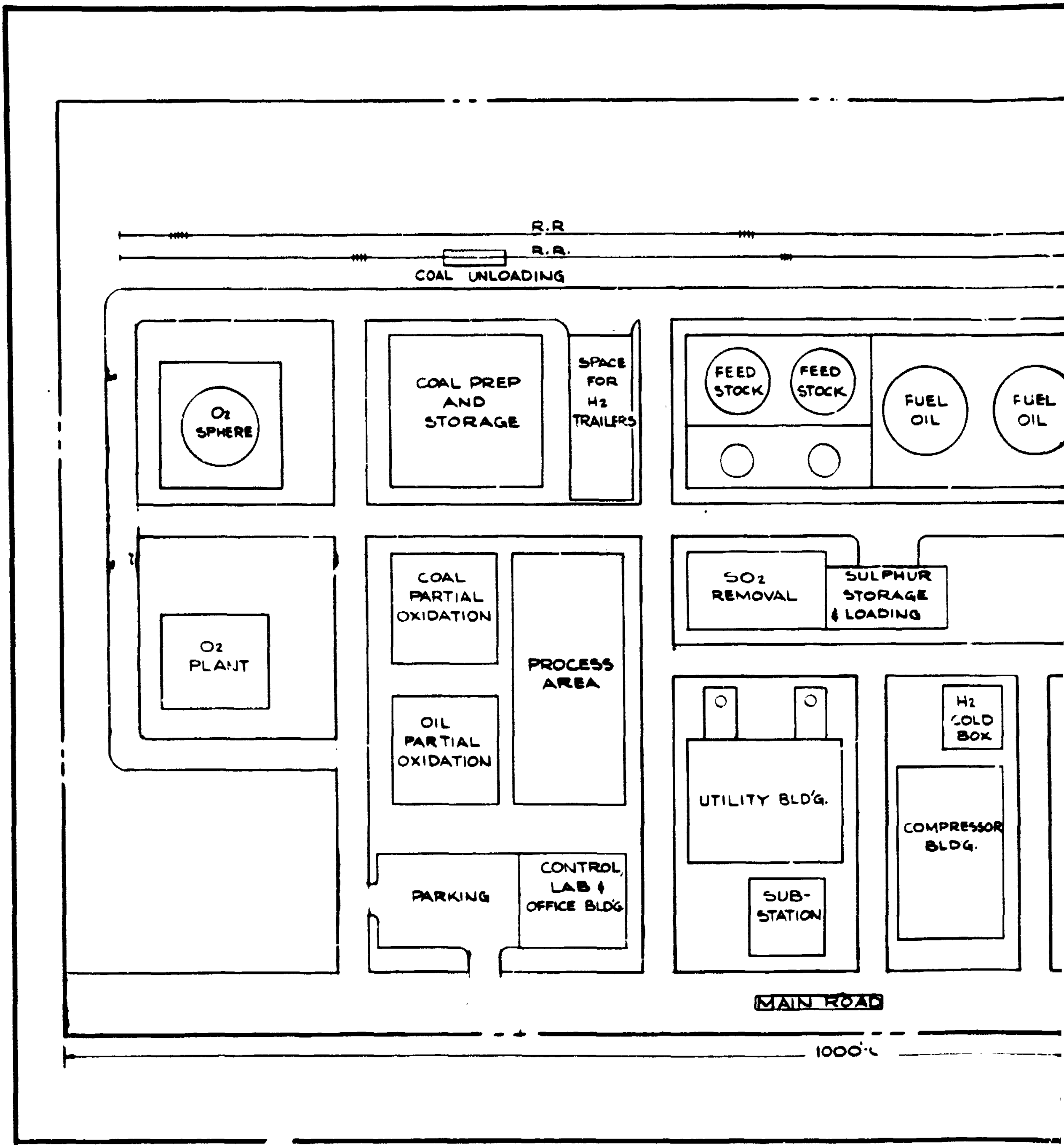
Interconnecting Piping Systems Within Plant

Pumping Systems As Required for Feedstocks, Fuels, Utilities and Services

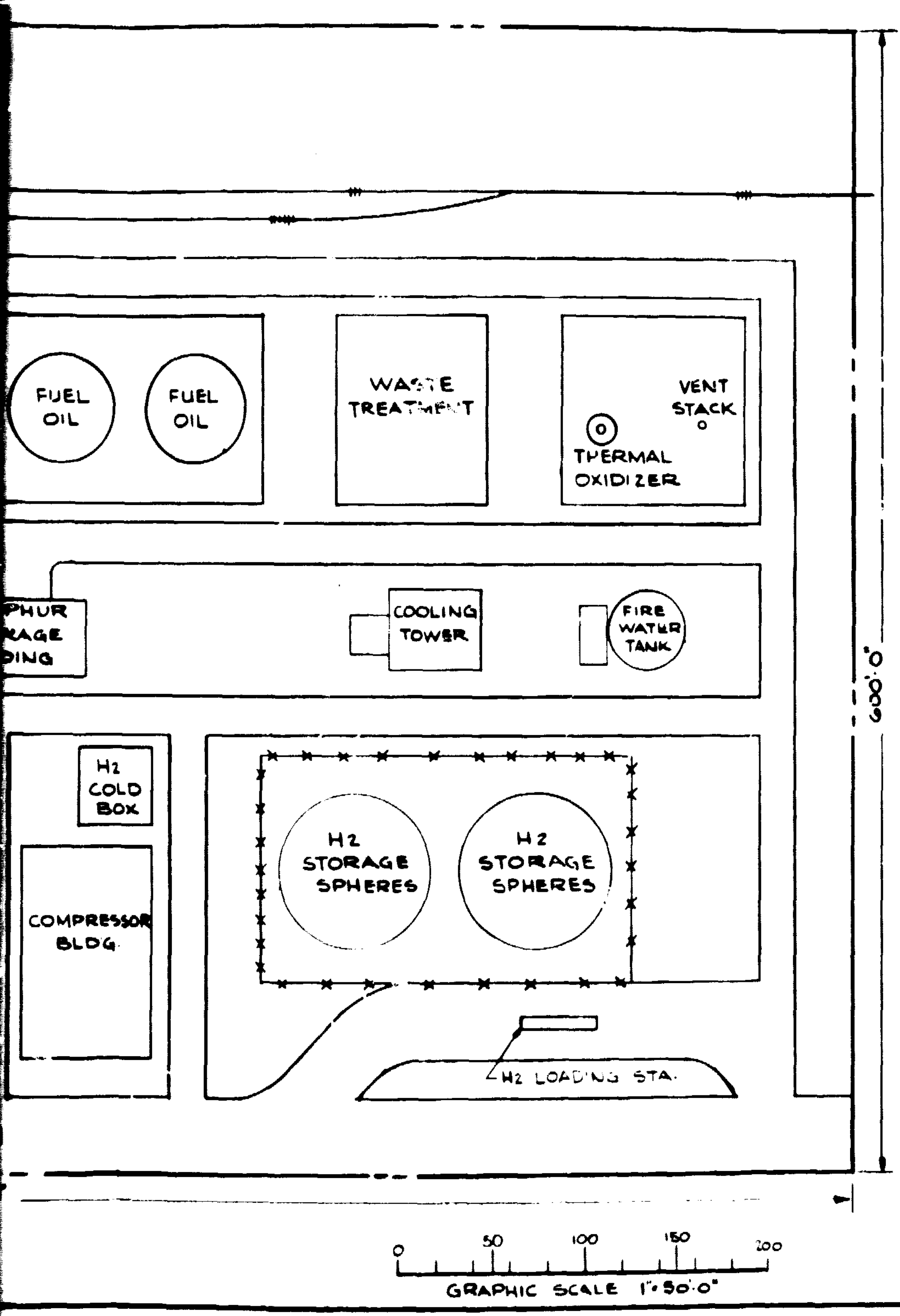
Other

Boundary Tie-Ins with Existing KSC Facilities

Residual Oil and Fuel Oil Piping Beyond Plant Boundary (1,000 ft. of Each at Grade Level)



R.R
R.R.
COAL UNLOADING
O_2 SPHERE
COAL PREP AND STORAGE
SPACE FOR H_2 TRAILERS
FEED STOCK
FEED STOCK
FUEL OIL
FUEL OIL
O_2 PLANT
COAL PARTIAL OXIDATION
PROCESS AREA
OIL PARTIAL OXIDATION
SO_2 REMOVAL
SULPHUR STORAGE & LOADING
UTILITY BLD'G.
SUB-STATION
H_2 COLD BOX
COMPRESSOR BLDG.
PARKING
CONTROL, LAB & OFFICE BLDG
MAIN ROAD
1000'-



BECHTEL
NEW YORK

NASA FEASIBITY STUDY
LIQUID HYROGEN PLANT

PLOT STUDY FOR
SPACE ALLOCATION

11536 FIG-3

FOLDOUT FRAME 3

PROCESS DESCRIPTION

An overall block flow diagram for the process is given in Figure 1 for Heavy Oil Gasification, and in Figure 2 for Coal Gasification. Material balances for these are indicated on the block flow diagrams.

The overall process plant is divided into ten sections which are discussed later. These are:

Plant No.	Description
1	Air Separation
2	Partial Oxidation - Oil
2A1	Partial Oxidation - Coal
2A2	Coal Receipt and Preparation
3	High Temperature Shift
4	Rectisol
5	Fine Desulfurization
6	Low Temperature Shift
7	Bulk CO_2 Removal
8	Dehydration and Trace CO_2 Removal (Molecular Sieves)
9	Hydrogen Liquefaction
10	Stretford Sulfur Recovery

PLANT 1

Air Separation

The air separation plant is sized to the needs of the coal gasification system (approximately 207 short tons/day). This provides a surplus capacity of about 76 tons/day when running on oil. The surplus production will be stored as liquid oxygen, for use when the coal gasifier is being put through shakedown runs.

Nitrogen by-product will be used as a general-purpose inert gas and for regeneration of the molecular sieves.

The principal equipment is as follows:

Inlet air filter and compressor including after coolers and surge drum

Low pressure reversing type cold box containing heat exchangers, two distillation columns and two expansion turbines - one of them is a spare

Oxygen compressors with after coolers

PLANT 2

Partial Oxidation - Oil

Heavy residual oil is preheated and fed with steam and oxygen to a specially developed burner which directs the reactants into a refractory lined partial oxidation chamber. The reaction conditions are controlled closely to preset pressures and temperatures which optimize conversion. The instrumentation system for the controls has been developed in a history of over 100 operating plants.

The synthesis gas resulting from partial oxidation is passed into a quenching zone, in which the gas temperature is reduced to a level satisfactory for processing in unlined steel equipment and in which large quantities of high pressure steam are produced.

The quenched synthesis gas is scrubbed free of traces of ash and carbon particles.

Soot produced in the quench zone and scrubbing zones is recovered and recycled. This is a Texaco Development Corporation process.

The principal equipment is as follows:

The partial oxidation reactor, brick-lined, with special burner and with quench bottom section.

Other vessels include -

Carbon scrubbing vessel

Naphtha quench decanter

Water flash separator

Naphtha stripper
overhead accumulator

Naphtha stripper

Slurry stripper

Fired heaters for -

Process water vaporizer

Steam-oil preheater

Naphtha stripper reboiler

Tanks required are -

Oil day tank

Feed slurry tank

Black water slurry tank

Naphtha day tank

The biggest tank has a capacity
of about 1500 bbl.

Three air coolers, the biggest of which has a duty of 4.5 MM Btu/Hr.

Four heat exchangers, the biggest of which has a duty of 10 MM Btu/Hr.

Numerous small pumps, the biggest of which has a flow of 320 GPM and pressure differential of 80 psi. The highest discharge pressure is about 800 psi. Some of these pumps have to handle slurry.

PLANT 2A.1

Partial Oxidation - Coal

Coal-water slurry is pumped to about 700 psig as a 50% (plus or minus) coal slurry. Texaco has developed special controls on the method of operation and the required coal particle size and particle size distribution.

The slurry is normally preheated and is fed to a specially developed burner which directs the reactants into a combustion chamber lined with high quality refractory inside a steel pressure shell. Reaction conditions in the combustion space are closely controlled by a system which is similar to that used for oil.

As for oil, the raw gas is passed to a quench, but in this case, bulk removal of ash is provided via a lock hopper of special design. The quenched gas, free of coarse ash but containing fly ash and soot, is scrubbed to reduce particulates. Soot recovery is similar in principle to the oil system.

This entire section is redundant and capable of independent operation when the oil-fed section is not running. If prolonged runs exceeding 7 or 8 days are planned on the coal unit (while running the oil plant), additional oxygen will have to be purchased.

A thermal oxidizer is provided for disposal of the raw gas from the shakedown runs of the coal-fed unit. The flue gas from this oxidizer will be scrubbed for SO_2 removal before venting to the atmosphere.

This is a proprietary process, however, the principal equipment is:

Coal slurry tank and pump

Brick-lined empty gasifier reactor including
a quench bottom section and ash removal
system having an innovative design of a
lock hopper

The remainder of the equipment is basically similar to that of Plant 2.

PLANT 2A.2

Coal Preparation

These facilities are conventional, consisting of hopper car unloading, bucket elevators to load the coal into the feed silos, reclaiming from silos via tunnel belt conveyors, conveying and elevating the prepared coal to silos from which the coal is fed to process. Processing of coal consists of milling it in a hot air swept ball mill, classifying the ground coal into a product fraction containing 80% minus 200 mesh, and an oversize fraction. The oversize fraction is returned to the mill. The product fraction is fed to the gasitication system as a 50% coal-water slurry.

The principal equipment consists of the following:

Rail car underground receiving hopper

Bucket elevator

Tunnel belt convyors

Inclined belt conveyor

Elevated hopper and hammer mill

Heater and ball mill

Air fan and classifier

Cyclone with dry hopper immediately above
the coal slurry tank of Plant 2A. 1

Dust collector

Gasifier coal feed silo

PLANT 3

High Temperature Shift

The particulate-free gas issuing from the gasification section (Plant 2 or 2A. 1) is saturated with water and is heated to about 650°F. It is then passed through a high temperature shift converter where most of the carbon monoxide in the gas is converted to hydrogen and carbon dioxide. Gas compositions before and after shift for oil and for coal are shown on the flow diagrams.

The synthesis gas and the shifted gas contain sulfur originating from the feed to the gasifier. A catalyst which will tolerate sulfur and still have satisfactory activity has been developed for the high temperature shift reaction. Carrying out the shift reaction at this point results in a simultaneous hydrogenation of sulfur compounds, converting them predominately to H_2S. This simplifies the separation of H_2S in Plant 4.

The principal equipment consists of:

> Three vessels packed with high temperature shift sulfur resistant hydrogenating catalyst.
>
> A chain of heat recovery equipment including waste heat boilers. The biggest exchanger has a duty of about 12 MM Btu/Hr.
>
> Two K.O. drums for condensate recovery

PLANT 4

Gas Purification (Rectisol)

The gases from the high temperature shift section are treated in a Rectisol system, which uses methanol at about minus 40°F to remove the hydrogen sulfide, carbonyl sulfide and carbon dioxide from the product gases. The system uses the conventional absorber-stripper sequence, in which the contaminants are removed in the absorber, producing a purified synthesis gas in the overhead and recovering the contaminants from the methanol solvent in a stripper which takes the contaminants overhead and produces a regenerated solvent for recycle to the absorber.

The Rectisol system was used for this study since it has an established record in many commercial applications for producing adequately purified gases from heavy oil or coal gasification.

Although this is a proprietary process, the principal equipment is given below:

Absorber packed or trayed stripper packed or trayed

Flash vessel

Methanol/water separator

Heat exchange equipment including chillers and reboiler

Refrigeration package

Miscellaneous pumps and tankages

PLANT 5

Fine Desulfurization

The purified gases from the Rectisol system are reheated and passed over a zinc oxide bed which removes to almost a vanishing point any residual sulfur in the product gas. This protects the copper-based low temperature shift catalyst, which is extremely sensitive to sulfur.

This plant may be eliminated if the low temperature shift (Plant 6) is eliminated. This simplification can be evaluated later.

This unit consists solely of a vessel packed with the zinc oxide and a stand-by vessel so that the zinc oxide can be replaced without a plant shut-down, and a heat exchanger located in Plant 2.

PLANT 6

Low Temperature Shift

The completely desulfurized gas is mixed with steam and fed to the low temperature shift reactor. Here, carbon monoxide conversion of hydrogen and carbon dioxide is completed at a temperature most favorable for this conversion (about 450°F). Carbon monoxide content is reduced to about 1 percent.

This plant may be eliminated if the hydrogen liquefaction unit (Plant 9) can tolerate upward of 2% CO, which could be achieved in the high temperature shift (Plant 3).

The principal equipment consists only of a packed vessel and a heat exchanger.

PLANT 7

Bulk CO_2 Removal

The gas after low temperature shift is cooled and all condensate separated to remove the bulk of the contained water. The carbon dioxide content of the gas is reduced to about .05 mol percent in a Selexol system. Other bulk CO_2 removal processes are possible, and these could be evaluated before final selection is made. The carbon dioxide removed from the product gas in this section will be vented to the atmosphere since this gas is ecologically acceptable.

Although this is a proprietary process, the principal equipment consists of the following:

Absorber with packed sections

Stripper with packed sections

Heat exchangers including two air coolers and chillers

Knock-out drum

Miscellaneous pumps and tankages

PLANT 8

Dehydration and Trace CO_2 Removal (Molecular Sieves)

The product gas from the bulk CO_2 removal section, containing about .05 percent carbon dioxide, and traces of water must be treated to reduce these components down to 5 ppm and 1 ppm respectively before entering the hydrogen liquefaction section. These low levels are achieved by passing the gas through a bed of molecular sieves. Two vessels filled with molecular sieves are used alternatively. One bed is regenerated, while the other is contacting the product gas. The water and carbon dioxide removed from the gas by the molecular sieves are stripped from the sieves using heated nitrogen from the air separation plant.

The principal equipment items are:

- Coolers including a chiller
- Knock-out drum
- Vessel packed with molecular sieve with a stand-by capacity
- Fired heater for the regeneration cycle

PLANT 9

Hydrogen Liquefaction

The dried, CO_2-free gas from the molecular sieves is liquefied in a cascade-refrigerated system, using liquid nitrogen for hydrogen liquefaction. Remaining impurities such as carbon monoxide, nitrogen, argon, etc., are removed from the hydrogen in the liquefaction unit. Ortho-para hydrogen shift is accomplished via a suitable catalytic process. Product liquid hydrogen has a purity better than 99.99%.

The principal equipment is basically as follows:

- Cold box including adsorbents for contaminants removal and catalyst for ortho to para hydrogen conversion

Recirculating nitrogen compressors including coolers, after coolers and chillers

Hydrogen recycle compressors including inter-coolers, after coolers and chillers

A refrigeration package for chilling to 40°F.

PLANT 10

Sulfur Recovery

The sulfur-bearing components and carbon dioxide which were removed from the product gas after high temperature shift (above) are treated in a Stretford process plant. The gas is contacted with a lean solution which converts the hydrogen sulfide to sulfur. The sulfur may be recovered either as a filter cake or as liquid.

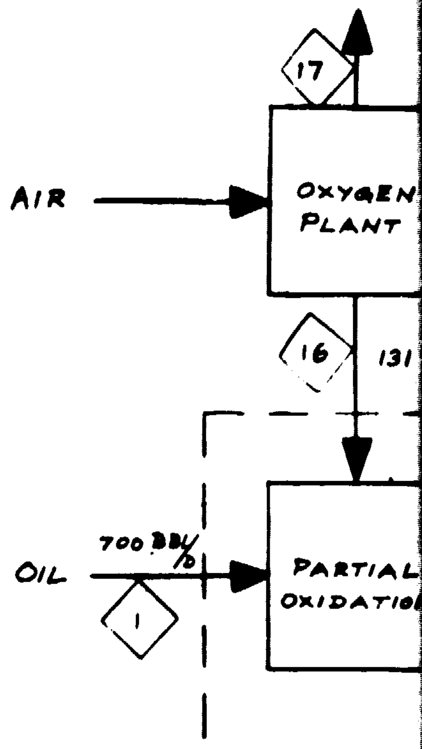
This is also a proprietary process. The principal equipment consists of the following:

Absorber with surge bottom capacity

Oxidizer with air blower

Slurry tank and filter

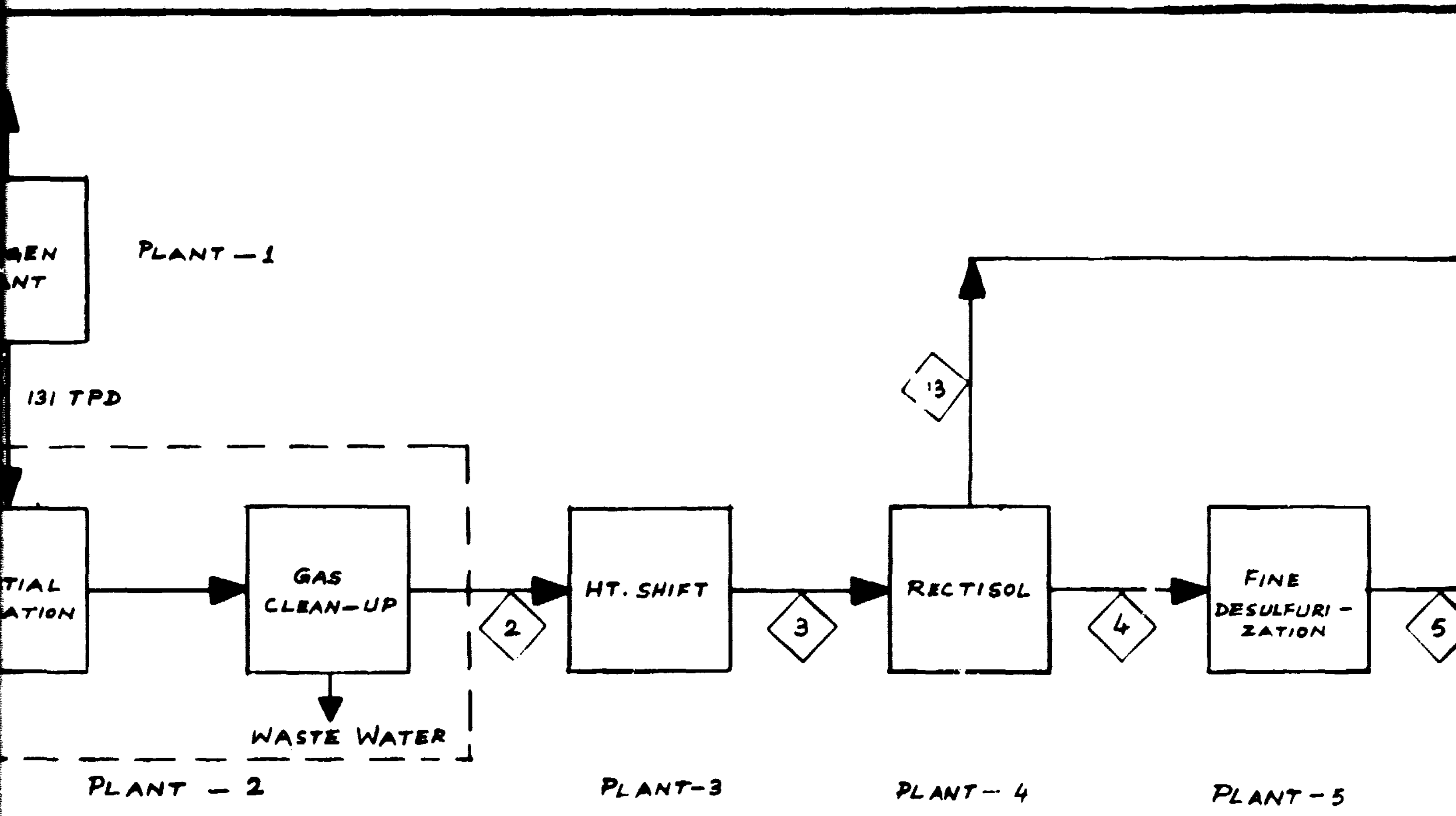
Miscellaneous pumps and tankages including a slurry pump



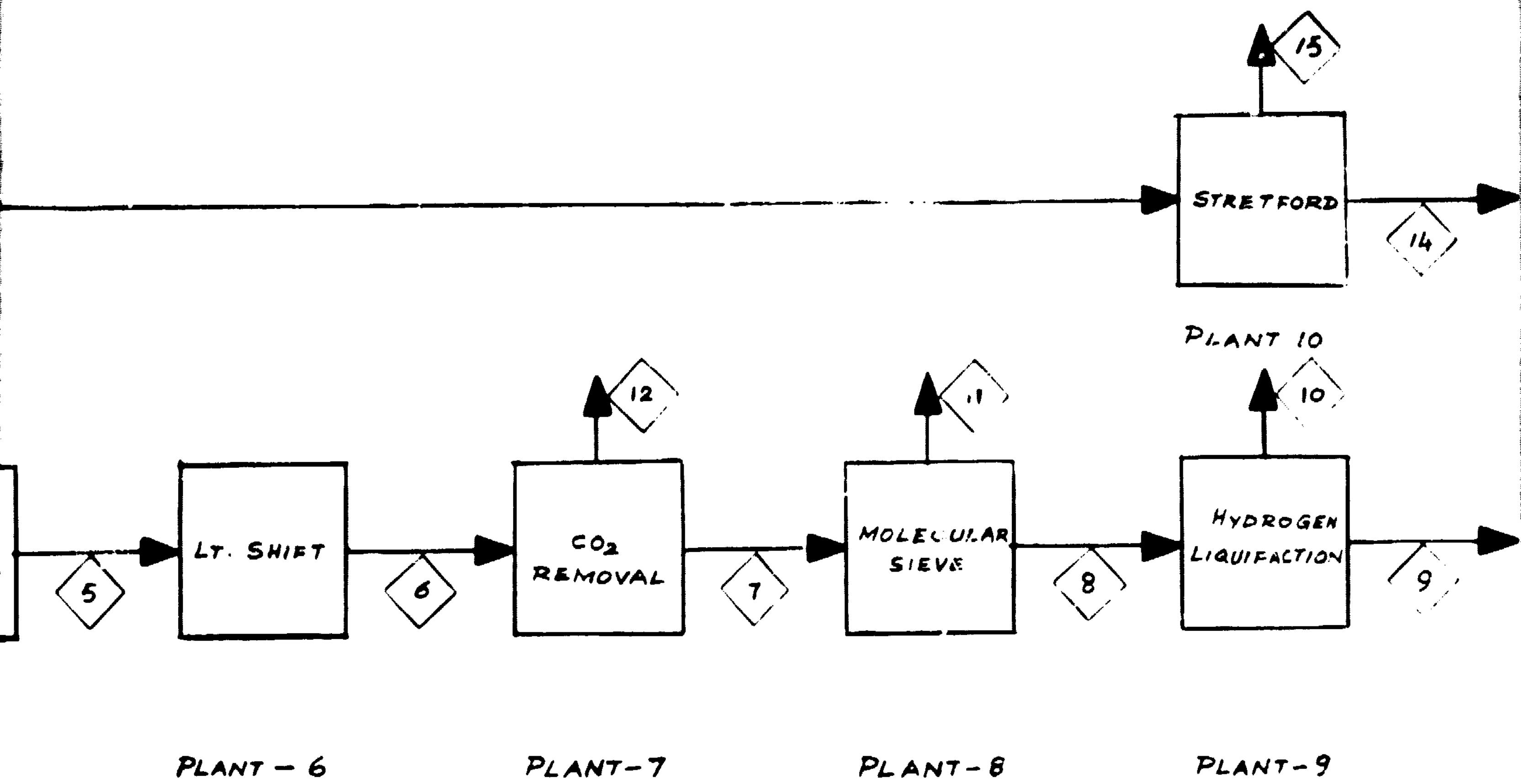
1	
PROPERTY	VALUE
°API	6.20
WT (%)	
C	86.43
H	10.01
N	1.00
O	—
S	2.50
ASH	0.06
LBS/HR	10,510.00

	2		3		
COMPONENT	MOLE %	M/HR	MOLE %	M/HR	MOLE
CH_4	0.69	9.30	0.48	9.30	0.
H_2	43.67	586.31	61.04	1184.83	91.
CO_2	2.97	39.88	32.89	638.44	0.
CO	51.53	691.71	4.80	93.24	7.
O_2	—	—	—	—	—
N_2	0.31	4.12	0.21	4.12	0.
A	0.26	3.45	0.18	3.45	0.
H_2S	0.54	7.30	0.40	7.67	—
COS.	0.03	0.37	—	—	—
S	—	—	—	—	—
TOTAL	100.00	1342.44	100.00	1941.05	10

FOLDOUT FRAME |



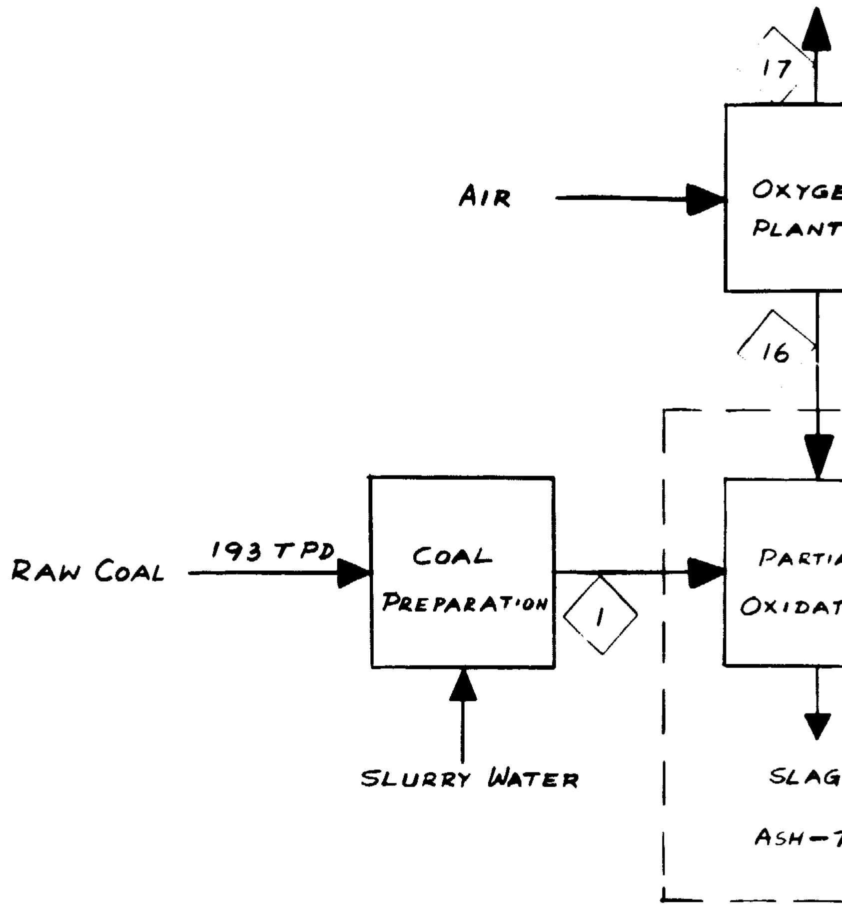
4		5		6		7		8		9	
MOLE %	M/HR	MOLE %	M/HR	MOLE %	M/HR	MOLE %	M/HR	MOLE %	M/HR	MOLE %	M/HR
0.72	9.30	0.72	9.30	0.68	9.30	0.71	9.18	0.71	9.18	–	–
91.48	1178.52	91.48	1178.52	91.96	1254.85	97.38	1250.00	97.43	1250.00	99.99	1250.00
0.01	0.12	0.01	0.12	5.60	76.46	0.05	0.64	–	–	–	–
7.20	92.75	7.20	92.75	1.21	16.40	1.27	16.34	1.27	16.34	–	–
–	–	–	–	–	–	–	–	–	–	–	–
0.32	4.08	0.32	4.08	0.30	4.08	0.32	4.07	0.32	4.07	0.01	0.12
0.27	3.43	0.27	3.43	0.25	3.43	0.27	3.4-	0.27	3.43	–	–
–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	–
100.00	1288.20	100.00	1288.20	100.00	1364.52	100.00	1283.66	100.00	1283.02	100.00	1250.12



	10		11		12		13		14		15	
M/HR	MOLE %	M/HR	MOLE %	M/HR	MOLE %	M/HR	MOLE %	M/HR	MOLE %	M/HR	MOLE %	M/
–	27.90	9.18	–	–	0.15	0.12	–	–	–	–	–	–
50.00	–	–	–	–	6.00	4.85	0.97	6.31	–	–	0.98	6
–	–	–	100.00	0.64	93.77	75.82	97.77	638.32	–	–	98.93	63
–	49.66	16.34	–	–	0.07	0.06	0.08	0.49	–	–	0.08	[illegible]
–	–	–	–	–	–	–	–	–	–	–	–	
.12	12.01	3.95	–	–	0.01	0.01	0.01	0.04	–	–	0.01	[illegible]
–	10.43	3.43	–	–	–	–	–	0.02	–	–	–	[illegible]
–	–	–	–	–	–	–	1.17	7.67	–	–	–	
–	–	–	–	–	–	–	–	–	–	–	–	
–	–	–	–	–	–	–	–	–	100.000	7.29	–	
50.12	100.00	32.90	100.00	0.64	100.00	80.86	100.00	652.85	100.000	7.29	100.00	4

FOLDOUT FRAME 3

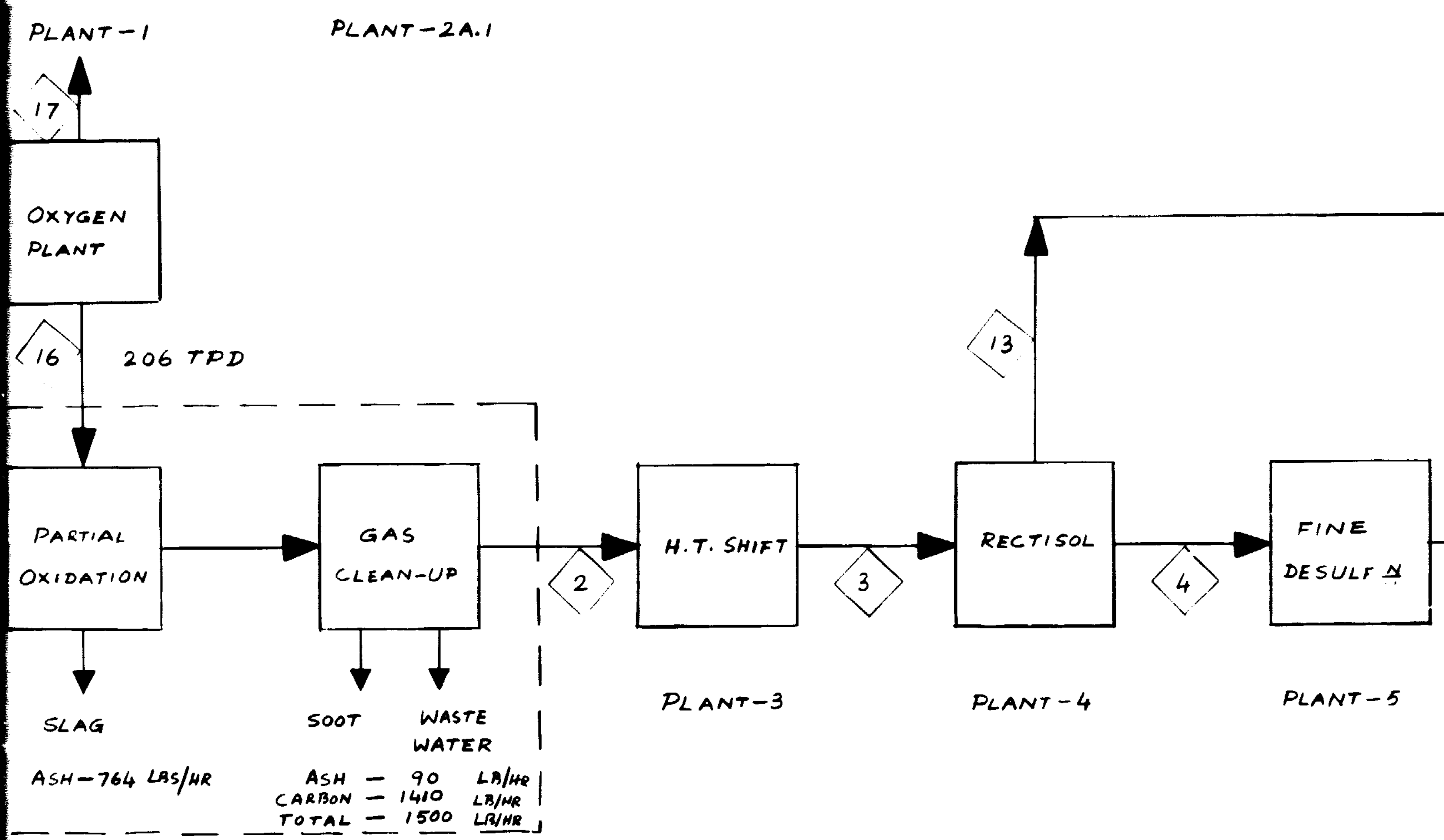
PLANT-2A.2



1

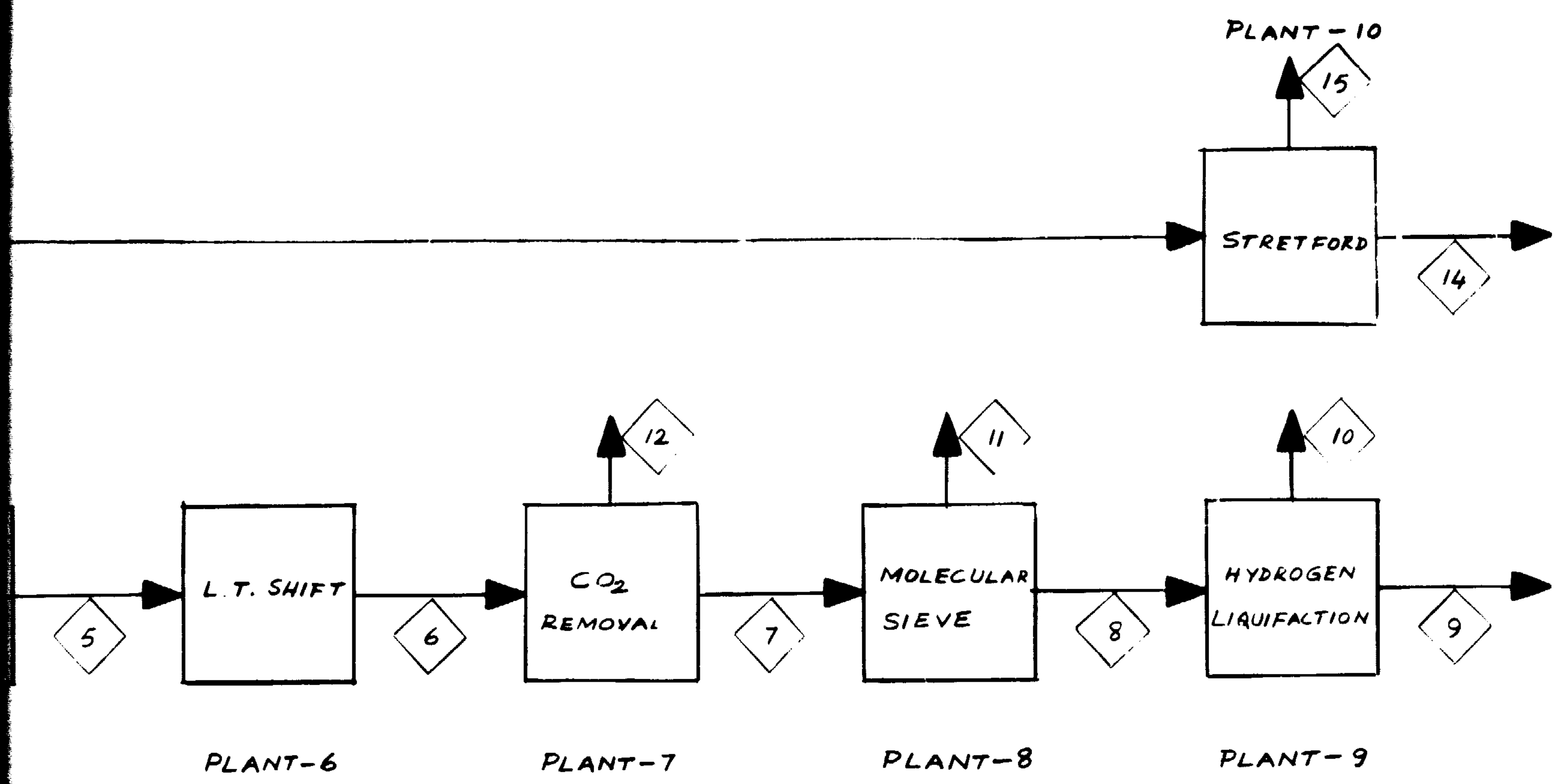
PROPERTY	VALUE
WT(%)	
C	85.33
H	4.13
N	1.40
O	2.99
S	0.84
ASH	5.31
COAL, LBS/HR	16,089.30
COAL, TPD	193.10
WATER SLURRY, LBS/HR	13,163.40

	2		3	
COMPONENT	MOLE %	M/HR	MOLE %	M/HR
CH_4	0.09	1.47	0.06	1.47
H_2	32.33	500.56	53.07	1184.83
CO_2	16.22	251.12	41.90	935.39
CO	50.22	777.51	4.18	93.24
O_2	–	–	–	–
N_2	0.52	7.98	0.36	7.98
A	0.35	5.40	0.24	5.40
H_2S	0.26	4.00	0.19	4.20
COS	0.01	0.20	–	–
S	–	–	–	–
TOTAL	100.00	1548.24	100.00	2232.51



	4		5		6		7		8		9	
R	MOLE %	M/HR	MOLE %	M/HR	MOLE %	M/HR	MOLE %	M/HR	MOLE %	M/HR	MOLE %	M/H
.47	0.11	1.47	0.11	1.47	0.10	1.47	0.10	1.47	0.10	1.47	—	
4.83	91.63	1178.52	91.63	1178.52	92.10	1254.85	97.50	1250.00	97.60	1250.00	99.99	1250.
5.39	0.01	0.12	0.01	0.12	5.60	76.46	0.10	0.64	—	—	—	—
3.24	7.21	92.75	7 21	92.75	1.20	16.40	1.30	16.34	1.30	16.34	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—
7.98	0.62	7.98	0.62	7.98	0.60	7.98	0.6	7.98	0.60	7.98	0.01	0.
5.40	0.42	5.40	0.42	5.40	0.40	5.40	0.4	5.40	0.40	5.40	—	—
4.20	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	—	—	—	—	—	—	—	—	—
2.51	100.00	1286.24	100.00	1286.24	100.00	1362.56	100.00	1281.83	100.00	1281.19	100.00	125

FOLDOUT FRAME 2



	10		11		12		13		14		15	
/HR	MOLE %	M/HR	MOLE %	M/HR	MOLE %	M/HR	MOLE %	M/HR	MOLE %	M/HR	MOLE %	M/
	4.70	1.47	–	–	–	..	–	–	–	–	–	–
0.00	–	–	–	–	6.00	4.85	0.70	6.31	–	–	1.10	10.
–	–	–	100.00	0.64	93.90	75.82	98.80	935.27	–	–	98.80	935
–	52.60	16.34	–	–	0.10	0.04	0.10	0.49	–	–	0.10	0
–	–	–	–	–	–	–	–	–	–	–	–	–
.12	25.30	7.86	–	–	–	–	–	–	–	–	–	–
–	17.40	5.40	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	0.40	4.20	–	–	–	–
–	–	–	–	–	–	–	–	–	–	–	–	–
–	–	–	–	–	–	–	–	–	100.00	4.20	–	–
50.12	100.00	31.07	100.00	0.64	100.00	80.71	100.00	946.27	100.00	4.20	100.00	946

FOLDOUT FRAME 3

SULFUR
1.6 TPD
(DESIGN - 7.7 TPD) *

14

HYDROGEN
30 TPD

9

NOTES

1) BASIS :- DRY GAS ONLY

* 2) FOR COAL CONTAINING 4 %W SULFUR

15		16		17	
LE%	M/HR	MOLE%	M/HR	MOLE%	M/HR
-	-	-	-	-	-
1.10	10.51	-	-	-	-
3.80	935.27	-	-	-	-
0.10	0.49	-	-	-	-
-	-	99.00	532.00	-	-
-	-	-	-	100.00	2021.70
-	-	1.00	5.40	-	-
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
00.00	946.27	100.00	537.40	100.00	2021.70

BECHTEL
NEW YORK

N A S A

LIQUID HYDROGEN
BY
COAL PARTIAL OXIDATION

JOB No.	DRAWING No	REV.
11536	FIG. 2	0

FOLDOUT FRAME 4

UTILITIES DISCUSSION

Steam System

High pressure saturated steam will be generated at 500 psig pressure in two 75,000 lb/hr. package boilers. Two units will be supplied for flexibility and continuity of operation in the event of an outage of one of the units. The boilers will be equipped with economizers to provide heat recovery for maximum efficiency of operation.

The boilers will be suitable for oil firing using light oil or gas for ignition and start-up of a cold unit. Automatic combustion controls will be furnished to adjust the firing rate of the boilers based on changes in steam demand. Combustion air will be supplied through inlet silencers to forced draft fans which will be either electric motor or steam turbine driven units.

A furnace supervisory safety system incorporating all necessary safety features, including burners, igniters and flame scanners will be furnished together with suitable purge, combustion control, feedwater control and monitoring systems.

Two additional saturated steam levels at 150 psig and 50 psig, will be provided for process and auxiliary equipment use. The primary source of these levels will be from pressure reduction and exhaust of turbine drivers. The systems will be protected against over-pressure by suitable safety valves. The low pressure steam will be used for boiler feedwater deaeration, heating and steam tracing.

Boiler Feedwater System

The boiler feedwater system will incorporate a deaerating heater for preheating the boiler feedwater and for removing the non-condensible gases. Provisions will be made for suitable chemical feed from dosing pumps to remove any residual oxygen in the boiler feedwater. Two electric motor driven boiler feedwater pumps will be provided for supplying feedwater to the boilers. A steam driven boiler feedwater pump will be furnished for standby. Automatic recirculation control, to keep a safe minimum flow through the pumps, will be supplied. Three element boiler feedwater control, to the boilers, will be furnished together for internal boiler water conditioning.

Condensate Collection

Both high and low pressure condensate from the process area will be collected.

Water Treatment System

The details on the type of treatment, and the components required for providing suitable water for make-up steam generation and other plant use will need to be developed. Based on the pressure level of the boilers and influent water of potable quality, it is anticipated that the treated water equipment will be made up of two zeolite softners of approximately 150 gpm capacity each. A treated water storage tank of approximately 2500 Bbls. will be provided. Regenerant wastes will be discharged to a neutralization pit for pH adjustment prior to discharging through a monitoring station to the existing City sewer system.

Cooling Water System

The cooling water system will consist of an induced draft cooling tower designed to cool a total of 10,000 gpm of water from 111°F to 86°F at 79°F wet bulb temperature.

The normal flow of returned cooling water is to the top of the tower. The water from the basin flows to the cooling water pump sump. Two 500 hp circulating water pumps will be furnished. One will be motor driven and the other turbine driven. During normal operation, only one pump is required.

The quality of the make-up water will determine the scaling tendency and the amount of blowdown required to limit the solids concentration in the water. Suitable provisions will be made for chemical feed and proportioning systems to reduce tendencies and to provide for corrosion inhibition.

Firewater System

The firewater system will consist of a 15,000 bbls. capacity firewater storage tank, two 2500 gpm firewater pumps and a firewater loop with associated hydrants.

One firewater pump will be motor driven. The second pump is a standby diesel driven unit which will automatically start up when the loop pressure drops below a predetermined set point.

Compressed Air System

The compressed air supply for both plant and instrument needs will be provided by two air compressors, one electrically driven and one diesel driven. The two machines will be cross-connected to two air receivers and dryers. The diesel driven air compressor will automatically start upon sensed low air pressure and upon power failure.

Each air dryer will consist of two vessels charged with solid granular dessicant and will be sized to dry the instrument air requirements at 100°F and 100% R.H. to a dew point of -40°F. The plant instruments are protected by passing the dried air through air filters to filter out any dessicant fines that might possibly be carried over from the drying vessels.

Environmental Protection

The oil storage and oxygen storage areas will be diked. Oil and process spillage will be collected through a system of process sewers which will discharge into the waste treatment system, consisting of an API type separator, prior to discharge into existing sewage systems at the battery limits.

Dust collection systems are provided in the coal system to collect and recycle coal dust.

Other solids such as spent catalysts and chemicals, would be recycled or trucked away.

MOBILE AND MOVABLE EQUIPMENT

A switching engine is provided for switching and positioning coal cars.

A front-end loader is provided for handling and loading sulphur for disposal as well as any miscellaneous bulk loading work.

DESIGN ASSUMPTIONS AND CLARIFICATIONS

In preparing the Study and Estimate it has been necessary to make certain assumptions. In addition, certain clarifications are in order. These are as follows:

1. It has been assumed that the Liquid Hydrogen Plant will be located adjacent to existing Kennedy Space Center facilities and that the following will be available or accessible at the east boundary of the new facility:

   Access road
   Railroad spur for coal train access
   Primary electric power from dual sources for reliability
   City/potable water
   Raw/brackish water
   Interconnection with existing fire water system and fire alarm system
   Storm water, process and sanitary sewers into which the LH_2 Plant can discharge for treatment and/or disposal.

2. A plot study for space allocation has been prepared as shown in figure 3. It is assumed that a clean, clear, level site, approximately 600 ft. by 1000 ft in size, and devoid of underground obstructions is available and situated as stated above. It has been assumed that piling will not be required for equipment support on this site.

3. It has further been assumed that residual oil feedstock and fuel oil (low sulfur no. 3 or no. 4) will arrive by barge at an existing barge dock to which NASA has access. An allowance has been included for the installation of 1000 ft. each of low level, sleeper - supported, residual oil and fuel oil piping beyond the LH_2 plant boundary to connect to the barge dock. Barge-mounted pumps would serve to effect the transfer to storage.

4. Surface (storm water) drainage to open ditches is assumed to be acceptable. Process and sanitary sewers will be piped underground.

5. Potable water of city water quality is assumed to be available for all water uses other than fire water and utility/service water. This water will go directly to the potable/sanitary water system, to cooling tower make-upand to water treatment for boiler feedwater use.

6. Raw or brackish water is assumed to be readily available and acceptable for fire water and utility or service water use.

7. The scope of work contemplated does not include a maintenance building or maintenance building or maintenance equipment of any sort, as it has been assumed that such facilities and equipment will be readily available within the Kennedy Space Center complex.

8. Home Office costs include provisions for the preparation of "as built" drawings only to the extent of a marked-up reproduible sepia of P&ID's, underground electrical and piping drawings, electrical one-line diagrams, plot plans and equipment arrangement drawings.

9. No provision is included in the estimate for spare parts or for inventories of catalysts, chemicals, feedstocks, fuels or other operating or maintenance supplies.

10. It is contemplated that a period of approximately two months will be required for plant start-up.

11. The estimated cost of start-up assistance is not included in the capital cost estimate, but is set forth as a separate figure.

MANAGEMENT PLAN

Introduction

The "fast track" schedule required for this project, emphasizes the need for a close knit organization and a well considered plan of implementation. These needs can best be met by using the engineering-procurement-construction ("EPC") concept and a task force organizational format.

"EPC" Concept

The "EPC" concept places total responsibilty for all aspects of a project, including engineering, procurement and construction in the hands of one contractor.

The advantages of this approach are especially desireable in meeting the needs of a "fast track" schedule, since it allows for concurrent activities and close coordination among the various entities involved. It allows construction to start early and follow closely behind engineering, since priorities can be set on an area-by-area or drawing-by-drawing basis. Similarly the close interface with procurement activities allows for more expeditious selection of bidders, more realistic input of delivery needs and faster resolution of problems or changes which may arise in the manufacturing period.

Project Management

All aspects of the project will be under the direction of a project manager who will have total responsibility for the engineering, procurement, construction and management services. He will work closely and be the principal contact with NASA.

The managers of the engineering, procurement and construction efforts would report directly to the Project Manager, forming a close knit management team.

Project Engineering

To meet the critical nature of the schedule, close coordination is mandatory among the various design disciplines. To accomplish this, the engineering effort would be organized into a "task Force". The "task force", consisting of all the necessary design disciplines and technical specialists, would be physically located together. All the engineering work, performed by the "task force", would be directed by the Project Engineering Manager.

Procurement

Significant to project success are sound procurement decisions with particular emphasis on timely committment and delivery of major equipment and good material logistics control.

Procurement activities consists of purchasing, expediting and inspection. The focal point of these activities should be centered in the same office in which engineering design is being performed. By intergrating these activities into the "task force", a high degree of coordination is acheived resulting in a continuity of effort in the various stages, from specifying to delivery, involved in the procurement effort.

This approach, under the direction of a Project Procurement Manager; can result in significant improvements in delivery lead times.

Construction

The field construction organization, under the direction of the Site Construction Manager, is arranged to provide a complete service of planning, scheduling, craft supervision, engineering interpretation, quality control, cost control, subcontract administration, warehousing, material control, labor relations, accounting and safety.

Key construction personnel meet with the "task force" early in the engineering phase to contribute to such aspects as constructability, designs that minimize construction costs and time and priorities for the design team to follow.

Implementation Plan

Due to the planned "fast track" schedule, it is imperative that a number of items be resolved as expeditiously as possible.

Such items as the design basis and other key parameters would be agreed upon during a "kick-off" meeting between key NASA and Contractor personnel. In addition, various administrative aspects must be resolved such as approval requirements, channels of communications and identifying responsible personnel.

The Contractor must immediately staff the "task force" to accomplish the "front end" design activities such as the preparation of process flow diagrams, data sheets, material balances and layout studies. Simultaneously, due to the critical schedule, certain long delivery items, such as the O_2 plant, H_2 storage spheres and compressors, must be specified and issued for quotation. Further, process licensing agreements must be negoitated within the first month.

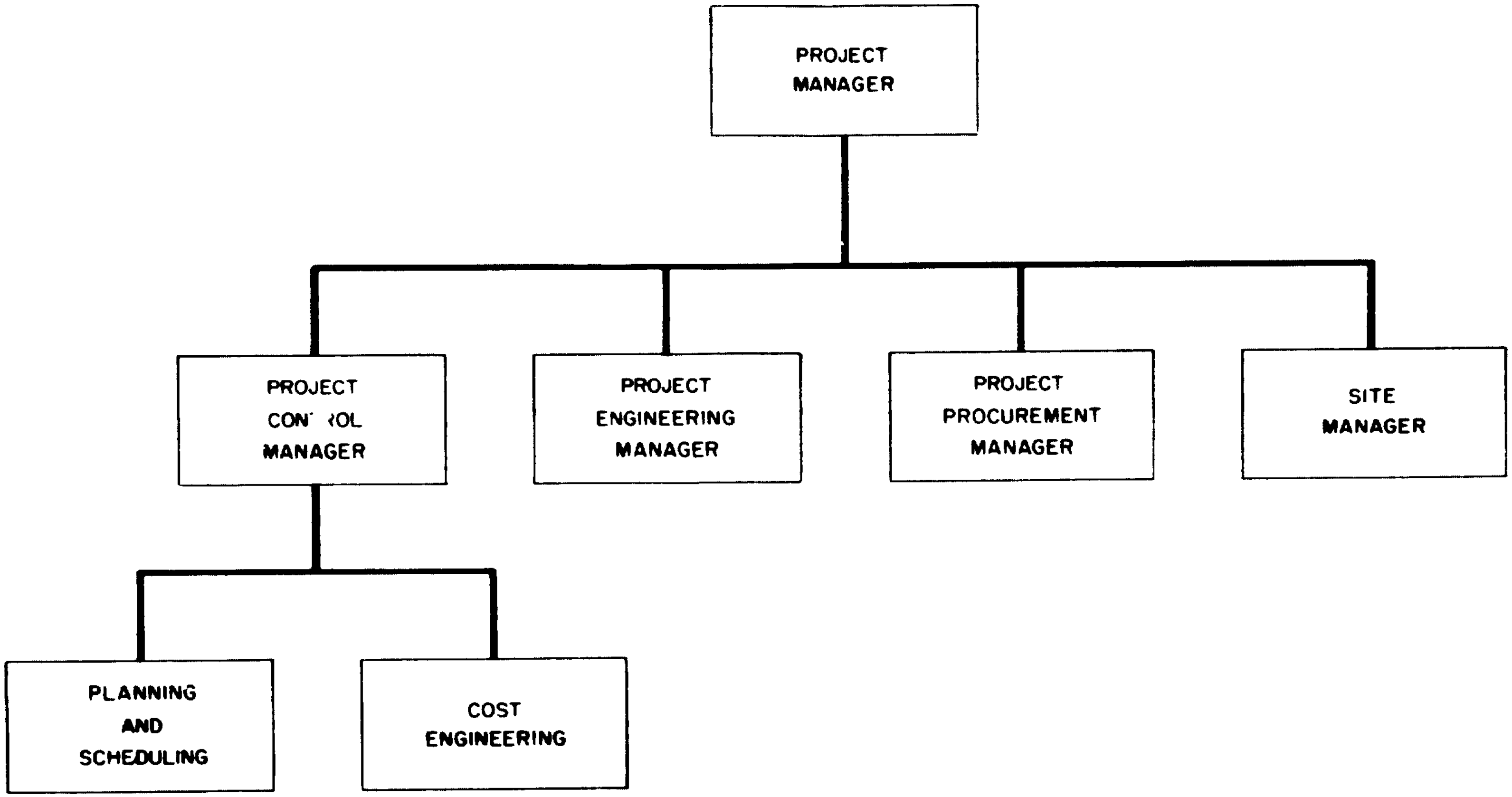
To maintain the momentum of the "fast track" schedule, quick turn-around will be required on items requiring NASA approval such as bid evaluations and possibly certain key technical matters. To accomplish this in the minimum amount of time, a NASA personnel with the appropriate approving authority should be resident in the Contractor's office.

Concurrent with the "front-end" engineering effort, planning and scheduling activities would include identifying priorities, preparing detail schedules showing the construction issues of key engineering drawings and documents, on-site delivery requirements for equipment and material and major construction activities.

Early procurement activities would include preparing a bidder's list based on inputs from NASA, previous experience and a quick survey of available shop space and delivery requirements.

As the project becomes defined various on-going schedule and cost controls must be initiated. Under the over-all direction of the Project Manager, detailed engineering, procurement and construction schedules are prepared and monitored. In addition, various other control documents will be maintained to monitor the issuing of design drawings, material requisitions, equipment deliveries and other major categories of design and procurement documents.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
FEASIBILITY STUDY - LIQUID HYDROGEN PLANT
PROJECT MANAGEMENT ORGANIZATION



OBJECTIVE SCHEDULE

Introduction

A project Schedule, excluding coal facilities, of 32 months, from Contract Award to Mechanical Completion, is contemplated as shown on the attached Objective Schedule. The coal facilities would be Mechanically Complete three months later, for a total schedule duration of 35 months.

Definition of Objective Schedule

The attached Objective Schedule list the key activities that form the critical path and/or have a major impact on the project. Upon award, detailed engineering, procurement and construction schedules would supersede the objective schedule.

Definition of Mechanical Completion

Mechanical Completion defines the point at which all material is installed and operable. That is, motors are wired up, piping is installed and hydrotested, controls are installed and connected to the panel, construction activities have ended and construction materials and tools have been removed. At this point start-up activities may begin, including the installation of catalysts and receiving fuel and raw materials.

Objective Schedule Discussions

Examination of the Objective Schedule reveals certain critical activities which must be evaluated in order to determine the confidence level of the schedule. These critical activities are:

- Long Delivery Equipment

  There are a number of long delivery items shown on the attached schedule. These include:

  Oxygen Plant
  Hydrogen Liquifaction Plant
  Nitrogen and Hydrogen Compressors
  Hydrogen Storage Spheres
  Electrical Substation

The delivery information, for these items, is based on recent experience as well as verbal information from various manufacturers of the particular piece of equipment. The deliveries, therefore, represent the present market conditions. While there are multiple sources of supply for all of the equipment to be used in the Project, these have not been enumerated in this Study pending development of a detailed bidder's list which would be part of the early detailed activities of the Project.

In order to minimize the impact, of these long deliveries, a number of steps must be taken.

First, these items must be specified and inquiry for quotes issued early. Bidders should be preselected and checked for their shop load and delivery capabilities prior to issuing bid inquiries so that those being asked to bid will be responsive to the schedule needs of the project.

Second, NASA approvals, if required, of bidders list, technical specifications and bid evaluations must be accomplished in a matter of days.

Third, the Contractor must be organized and managed in such a way as to be able to handle the necessary paperwork and issue the necessary technical data expeditiously, hand carrying documents where necessary. Further, follow-up contacts must be made to insure vendors received the bid inquiries, understand the project needs and will respond within the time alloted.

- Process Licenses

The schedule requires that an agreement be signed with the process licensors, within the first month of the project. From a practical viewpoint, this means that the process has been preselected and the one month time span is the time required to negotiate and finalize the agreement with the pre-selected licensors.

This is a very crucial step in the schedule because of the number of activities that are dependent upon the process design information supplied by the licensors. The procurment of the bulk of the equipment, excluding the oxygen and hydrogen liquification plants is dependent on this information.

- Critical Construction Activites

The construction activities which appear to be critical, are those that are dependent upon delivery of equipment and bulk materials. This includes piping, electrical and control wiring activities. A reasonable duration has been allowed for these activites and it would be difficult to reduce the time span allocated. Any significant slippage in equipment deliveries would have an adverse effect on these construction activities.

To control this aspect of the schedule, committments for equipment and bulk materials must be made early and the Contractor must maintain a high degree of vigilance over the performance of vendors during the fabrication stage to minimize delivery slippages.

Objective Schedule Confidence Analysis

The schedule, as presented, represents a reasonable and achievable goal required for the overall engineering, procurement and construction activities.

The delivery information is based on present experience and verbal discussions with vendors. It, therefore, reflects today's market sutuation. The delivery durations are expected to remain stable in the short run. Therefore, a high level of confidence exists in the expectation of fullfilling these goals.

Should the start of this project be deferred, the deliveries may be affected by changes in the capital construction market. An increase in petrochemical and/or utility construction or a speed-up of these kinds of projects now underway, would adversly affect the schedules.

Any improvement in the overall deliveries of equipment or bulks would shorten the schedule since the critical paths are through tha major equipment deliveries.

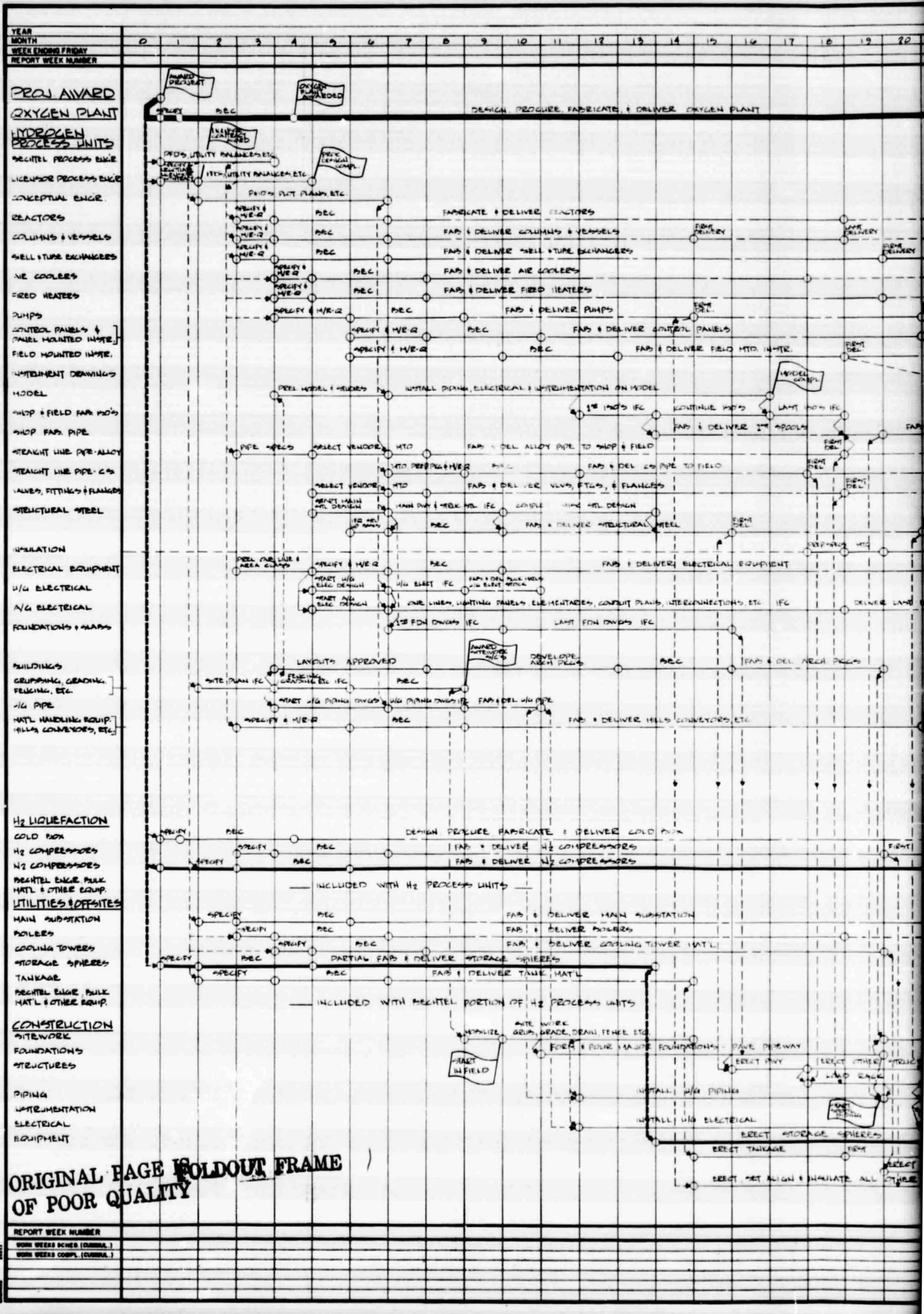
As discussed earlier, initial engineering activities are critical in that this is the part during which equipment specifications are prepared for solicitation of bids. This requires a fast build-up of engineering staffing and expeditious resolution of scope and licensing agreements. The ability of NASA, the Contractor and the Licensor to meet these goals must be weighed in evaluating the level of confidence for this aspect of the schedule.

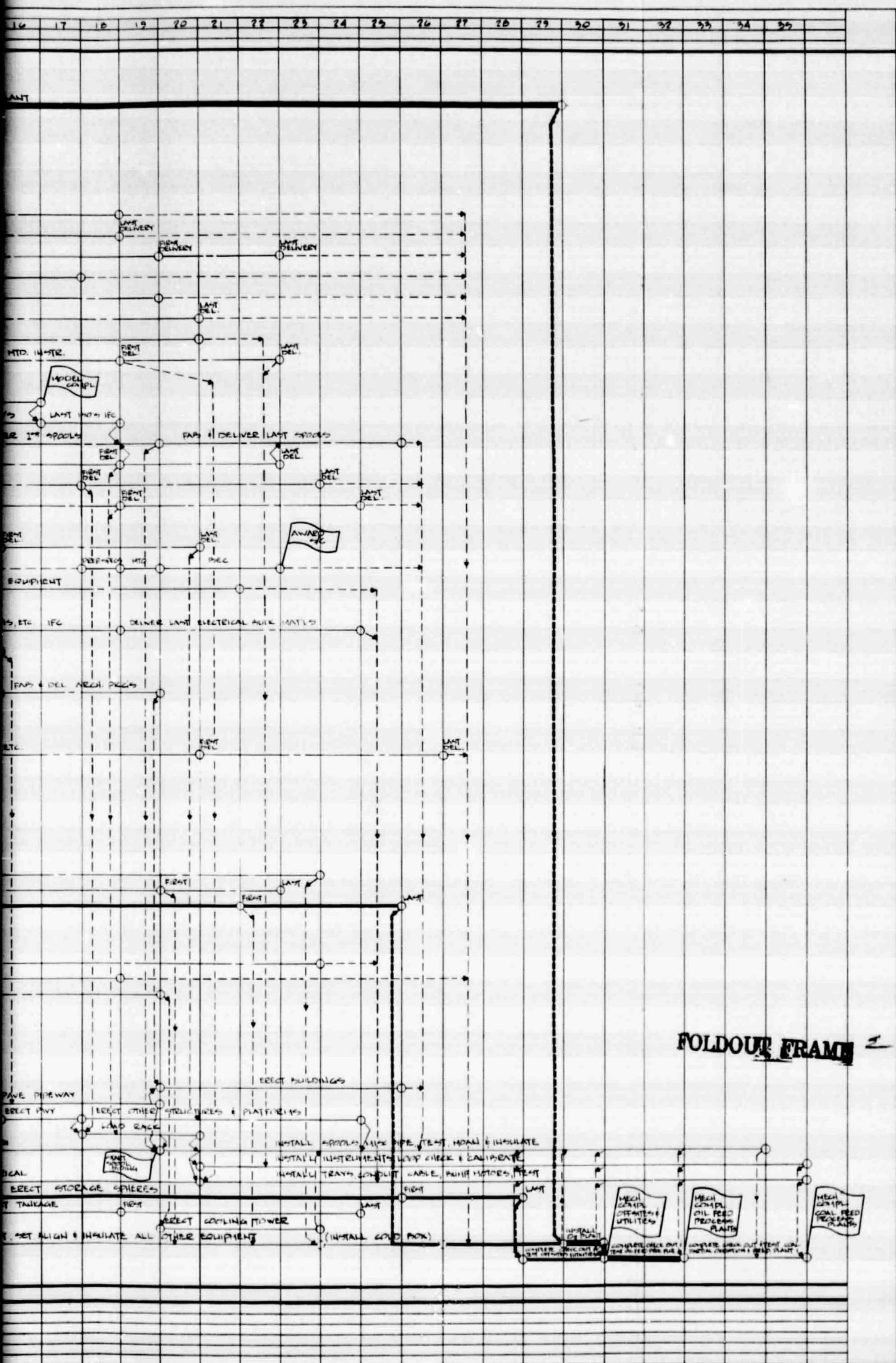
Beyond the early engineering phase, the schedule calls for a rapid prosecution of detail engineering and procurement. The durations allocated assume adequate staffing on the part of the Contractor and rapid approvals by NASA, or other agencies, when required.

Reasonable durations have been allocated for the construction activities considering the volume of work, staffing requirements, site degree congestion, site access and expected productivity in the area. The Contractor's ability to adequately supervise the work and maintain good labor relations must be considered since obviously the schedule would be adversely affected by poor productivity or labor stoppages.

Consideration must also be given to facilities not included in the scope of this project, but which may have an impact on the schedule. This includes adequate incoming power, utility tie-ins from existing facilities and the incoming rail spur. If the scope of this work is minor, it can easily be performed concurrently to this project, within the duration of the present schedule.

In conclusion, the schedule is reasonable based on today's market coupled with a quick starting, rapid engineering-procurement effort.


YEAR
MONTH
WEEK ENDING FRIDAY
REPORT WEEK NUMBER
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
PROJ. AWARD
OXYGEN PLANT
DESIGN, PROCURE, FABRICATE, & DELIVER OXYGEN PLANT
HYDROGEN PROCESS UNITS
A BECHTEL PROCESS ENGR
LICENSOR PROCESS ENGR
CONCEPTUAL ENGR.
C REACTORS
COLUMNS & VESSELS
E SHELL & TUBE EXCHANGERS
AIR COOLERS
F FIRED HEATERS
G PUMPS
J CONTROL PANELS & PANEL MOUNTED INSTR.
FIELD MOUNTED INSTR.
INSTRUMENT DRAWINGS
L MODEL
SHOP & FIELD FAB. ISO'S
SHOP FAB. PIPE
STRAIGHT LINE PIPE-ALLOY
STRAIGHT LINE PIPE-CS
VALVES, FITTINGS & FLANGES
M STRUCTURAL STEEL
N INSULATION
P ELECTRICAL EQUIPMENT
U/G ELECTRICAL
A/G ELECTRICAL
Q FOUNDATIONS & SLABS
R BUILDINGS
S GRUBBING, GRADING, FENCING, ETC.
U/G PIPE
T MAT'L HANDLING EQUIP. MILLS, CONVEYORS, ETC.
FABRICATE & DELIVER REACTORS
FAB & DELIVER COLUMNS & VESSELS
FAB & DELIVER SHELL & TUBE EXCHANGERS
FAB & DELIVER AIR COOLERS
FAB & DELIVER FIRED HEATERS
FAB & DELIVER PUMPS
FAB & DELIVER CONTROL PANELS
FAB & DELIVER FIELD MTD. INSTR.
INSTALL PIPING, ELECTRICAL & INSTRUMENTATION ON MODEL
FAB & DEL ALLOY PIPE TO SHOP & FIELD
FAB & DEL CS PIPE TO FIELD
FAB & DELIVER VLVS, FTGS, & FLANGES
FAB & DELIVER STRUCTURAL STEEL
FAB & DELIVER ELECTRICAL EQUIPMENT
LAYOUTS APPROVED
FAB & DELIVER MILLS CONVEYORS, ETC.
H2 LIQUEFACTION
COLD BOX
H2 COMPRESSORS
N2 COMPRESSORS
BECHTEL ENGR BULK MAT'L & OTHER EQUIP.
DESIGN, PROCURE, FABRICATE & DELIVER COLD BOX
FAB & DELIVER H2 COMPRESSORS
FAB & DELIVER N2 COMPRESSORS
INCLUDED WITH H2 PROCESS UNITS
UTILITIES & OFFSITES
MAIN SUBSTATION
BOILERS
COOLING TOWERS
STORAGE SPHERES
TANKAGE
BECHTEL ENGR. BULK MAT'L & OTHER EQUIP.
FAB & DELIVER MAIN SUBSTATION
FAB & DELIVER BOILERS
FAB & DELIVER COOLING TOWER MAT'L
PARTIAL FAB & DELIVER STORAGE SPHERES
FAB & DELIVER TANK MAT'L
INCLUDED WITH BECHTEL PORTION OF H2 PROCESS UNITS
CONSTRUCTION
SITEWORK
FOUNDATIONS
STRUCTURES
PIPING
INSTRUMENTATION
ELECTRICAL
EQUIPMENT
INSTALL U/G PIPING
INSTALL U/G ELECTRICAL
ERECT STORAGE SPHERES
ERECT TANKAGE
ERECT, SET, ALIGN & INSULATE ALL OTHER
REPORT WEEK NUMBER
WORK WEEKS SCHED (CUMUL.)
WORK WEEKS COMPL. (CUMUL.)



LEGEND

- REPORT DATE LINE - INDICATES PROGRESS AS OF FRIDAY CUTOFF FOR LINE TAPED
- CRITICAL PATH
- PROGRESS
- PRODUCTION WORK ITEMS (BECHTEL ONLY)
- FLOAT (RESTRAINT OR NON BECHTEL WORK WHEN TITLED)
- EQUIPMENT FABRICATION & DELIVERY
- SUB-CRITICAL PATHS
- ◇ SCHED. ISSUE TO CONSTRUCTION
- ◆ ISSUED COMPLETE
- ○ SCHED. WORK ITEM START OR END
- ● WORK ITEM STARTED - IF NO WORK ITEM FOLLOWS IT CAN ALSO INDICATE COMPLETION.

COMMON ABBREVIATIONS

A/G	ABOVE GROUND	MATL.	MATERIAL
APPVL	APPROVAL	MCC	MOTOR CONTROL CENTER
BEC	BID, EVALUATE & COMMIT.	MISC.	MISCELLANEOUS
BLDG.	BUILDING	MTO	MATERIAL TAKE OFF
C/A	CLIENT APPROVAL	PFD	PROCESS FLOW DIAGRAM
COLS	COLUMNS	PKG.	PACKAGE
COMP	COMPLETE	PLTF	PLATFORM
CS	CARBON STEEL	PNL	PANEL
DEL	DELIVER	PO	PURCHASE ORDER
DES	DESIGN	PREL	PRELIMINARY
DESIG	DESIGNATION	PROC	PROCESS
DWG	DRAWING	PWY	PIPEWAY
ELEC	ELECTRICAL	S/C	SUBCONTRACT
ELEM	ELEMENTARY	SCH	SCHEDULE
ENGR	ENGINEERING	SPECS	SPECIFICATIONS
EQUIP	EQUIPMENT	SS	STAINLESS STEEL
FAB	FABRICATE	ST	START
FDN	FOUNDATIONS	STD	STANDARD
HTR	HEATER	STG	STORAGE
IFA	ISSUE FOR APPROVAL	STL	STEEL
IFC	ISSUE FOR CONSTRUCTION	STM	STEAM
IFM	ISSUE FOR MODEL	STRUCT	STRUCTURAL
INST	INSTALL	SUB STA	SUB STATION
INSTR	INSTRUMENT	SW GR	SWITCH GEAR
INSUL	INSULATION	U/G	UNDERGROUND
INTCON	INTERCONNECTING	UTIL	UTILITIES
M/R	MATERIAL REQUISITION	VP	VENDOR PRINT
M/R-P	M/R FOR PURCHASE	IFE	ISSUE FOR ENGINEERING
M/R-Q	M/R FOR QUOTES		

OTHER

PRELIMINARY

FOLDOUT FRAME 2

NO.	DATE	REVISION	CHK. BY	APPROVED

BECHTEL

NASA
CAPE CANAVERAL, FLORIDA

FEASIBILITY STUDY
LIQUID HYDROGEN PLANT
OBJECTIVE SCHEDULE

JOB No.	DRAWING No.	REV.
11536	P & S - 1A	

NOTE: DRAWING ISSUES FOR WEEKLY PROGRESS REPORTING ARE NOT NECESSARILY A REVISION OF THE BASIC SCHEDULE.

SCHEDULE REVISIONS WILL BE NOTED BY A NEW REVISION NUMBER AND ENTRY ABOVE THE TITLE BLOCK IN THE USUAL MANNER.

DATE: MAY '75

WEEK NO. | ISSUE NO.

ESTIMATE SUMMARY

FEASIBILITY STUDY - LIQUID HYDROGEN PLANT

I. FIELD COSTS

Plant		$M
1.	Oxygen Plant	4,000
2.	Oil Partial Oxidation	3,000
2A1.	Coal Partial Oxidation	3,300
2A2.	Coal Preparation	1,300
3.	High Temperature Shift	3,100
4.	Rectisol	3,300
5&6.	Z_NO_2& Low Temp Shift	Incl. in Plant 3
7.	CO_2 Removal	1,000
8.	Molecular Sieves	100
9.	H_2 Liquefaction	9,000
10.	Stretford Unit	3,000
20&21.	SO_2 Scrubbing and Waste Treatment	400
30.	Offplots	22,000
	TOTAL DIRECT FIELD COSTS	53,500

II.	DISTRIBUTABLES (Indirect Field Costs & Non Manual Labor)	5,200
III.	HOME OFFICE (Process & Mechanical Design, Procurement & Project Managment)	7,700
IV.	START UP ASSISTANCE COSTS	100
V.	ESCALATION	10,000
VI.	OTHER	500
	TOTAL REVENUE EX FEE & CONTINGENCY	77,000
	CONTINGENCY	16,000
	FEE	4,000
	TOTAL PRICE	97,000

FEASIBILITY STYDY - LIQUID HYDROGEN PLANT

SUMMARY OF COST INCREMENTS INCLUDED IN THE ESTIMATE FOR USE OF COAL AS THE FEEDSTOCK

	TOTAL COST ($M)	Δ FOR COAL ($M)
PROCESS UNITS	$ 31,500	$ 7,800
OFF PLOTS	22,000	2,700
S/T DIRECT FIELD COSTS	$ 53,500	$ 10,500
DISTRIBUTABLES	5,200	250
HOME OFFICE	7,700	750
START - UP COSTS	100	--------
MOBILE EQUIPMENT	250	--------
CHEMICAL & CATALYSTS	250	50
ESCALATION	10,000	2,000
CONTINGENCY	16,000	3,000
FEE	4,000	750
TOTAL COSTS	$ 97,000	$ 17,300

FEASIBILITY STUDY - LIQUID HYDROGEN PLANT

COST INCREMENTS INCLUDED IN ESTIMATE REQUIRED FOR COAL AS FEEDSTOCK

PLANT NO.	DESCRIPTION	TOTAL COST ($M)	∆ FOR COAL ($M)
Process Units			
1	Oxygen Plant	$ 4,000	$ 900
2	Oil Partial Oxidation	3,000	----
2A1	Coal Partial Oxidation	3,300	3,300
2A2	Coal Preparation	1,300	1,300
3	High Temperature Shift	3,100	100
4	Rectisol	3,300	500
5 & 6	ZNO Unit & Low Temp. Shift	(Incl. in Plant 3)	----
7	CO_2 Removal	1,000	----
8	Molecular Sieves	100	----
9	H_2 Liquifaction	9,000	----
10	Stretford Unit	3,000	1,400
20	SO_2 Scrubbing	300	300
21	Waste Treatment	100	----
	S/T Process Units	$31,500	$ 7,800
OFF PLOTS			
	Storage Facilities	11,000	1,500
	Utilities	7,100	1,050
	Interconnecting Pipe	2,000	-----
	Site Work	550	50
	Buildings	400	-----
	Fire Protection Sys.	550	50
	Off Plot Foundations	400	50
	S/T Off Plots	$22,000	$ 2,700
TOTAL DIRECT FIELD COSTS		$53,500	$10,500

RCE - 35 A
10/70

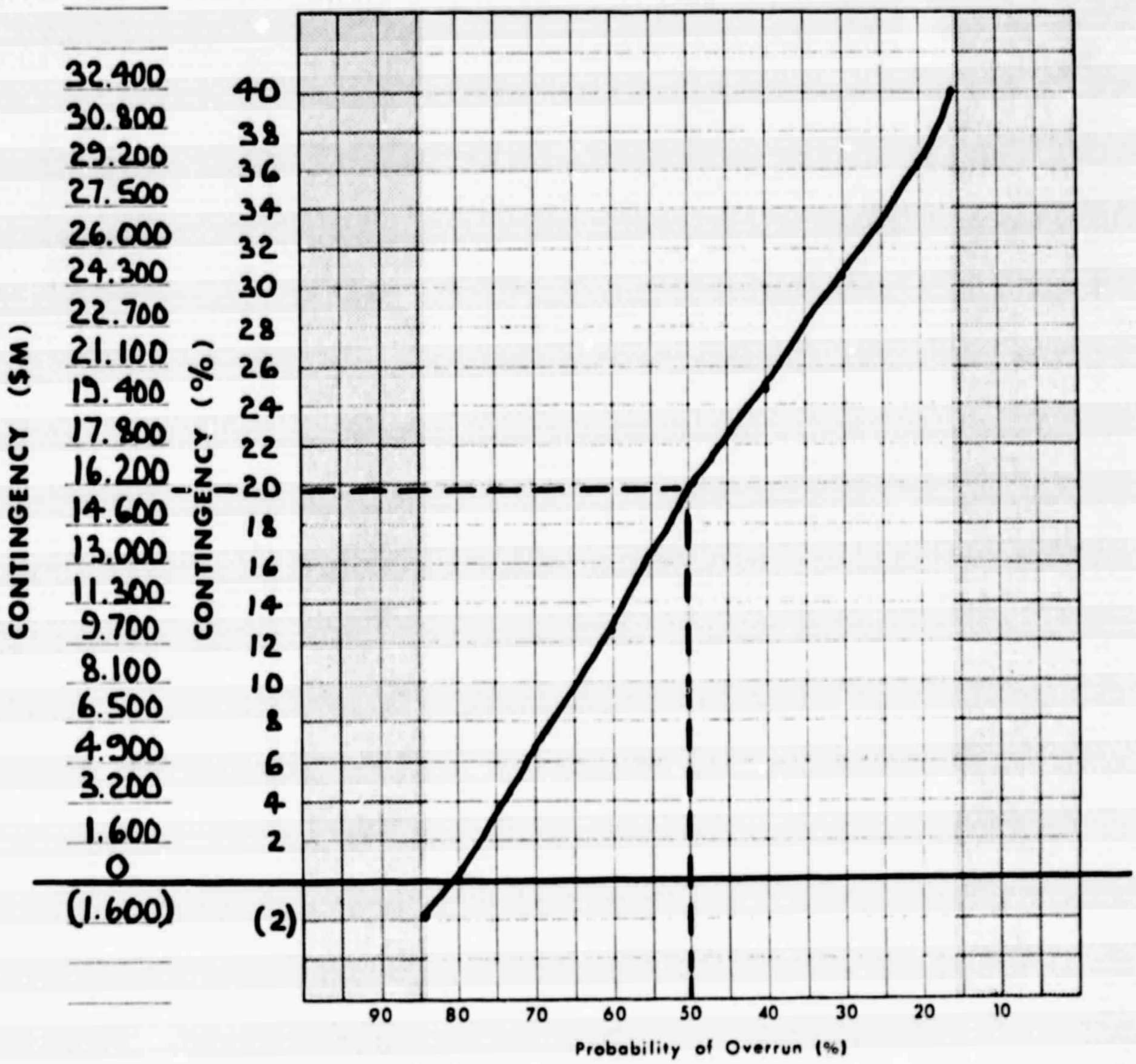
JOB NO 11536 /Client N.A.S.A.

Type of Plant LIQ H2.

ASSUMED Location CAPE CANAVERAL FLA.

Date 5/16/75

ANALYSIS OF RISK



ESTIMATE

Est. Cost Excl. Contingency $ 81.000.000

Accuracy Excl. Contingency* + 40 % - 2 %

Most Probable Cost $ 97.200.000

USE

Probability of Overrun 50 %

Contingency 20 %

$ 16.000.000

Estimate Accuracy
Incl. Contingency* + 21 % - 21 %

*Based on Standard Deviation

CASH FLOW ANALYSIS

BASED ON ESTIMATE & SCHEDULE

Note: The cash flow estimates shown herein are based on detailed engineering and procurement beginning in the third quarter 1975. All figures shown are in thousands of dollars.

Calendar Quarter and Year		Cash Flow per Quarter ($M)	Accumulation
3Q	1975	$ 800	$ 800
4Q	1975	4,800	5,600
1Q	1976	5,300	10,900
2Q	1976	11,600	22,500
3Q	1976	16,100	38,600
4Q	1976	17,100	55,700
1Q	1977	16,300	72,000
2Q	1977	10,100	82,100
3Q	1977	5,700	87,800
4Q	1977	4,200	92,000
1Q	1978	3,200	95,200
2Q	1978	1,800	97,000